Additional control based on ANFIS algorithm to improve transient current of converter-side in HVDC transmission system

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Abstract. Soft computing likes ANFIS now penetrating the control system, especially for power semi-conductor and power system controls. While, control of trigger angle is one of important role to deliver power through high voltage direct current (HVDC) transmission system effectively. Higher transient of current is one problem of HVDC on start-period, for up-ramp at 20 pu/s or higher. To cope this problem, the ANFIS control scheme is proposed to suppress the transient current in this research. Simulation results show that the proposed control is more effective to reduce the transient current compared to conventional PI control. Where, the peak overshoot of transient current is achieved at the value of 1.077 pu for the proposed control. While, the peak overshoot of transient current for conventional PI control is obtained at the value of 1.118 pu.

Keywords: ANFIS, addition control, HVDC, improve, transient time

1 Introduction

By growing-up of industrial and commercial load demands in power systems, and difficulty to develop power-plant near load center makes transmission line is the only one choice to connect the power-plant and the load center. So, load locations are commonly very far from power-plant sites. In this situation, the transmission line has a vital role to deliver amount of power successfully in all condition operations. While, high voltage direct current (HVDC) transmission system is set-up to substitute/replace high voltage alternating current (HVAC) transmission one, especially for area that the HVAC can not be installed such as: Long-distance transmission line, long submarine-cable and asynchronous inter-connected [1] [2]. Discussion of ultra-high voltage application included renewable energy for supply Europe-Asia continents through long-distance over head transmission line and sub-marine cable [3]. Starting strategy for HVDC-link using voltage source converter (VSC)-HVDC is introduced for supply passive network [4]. A new recovery control is developed in [5] to overcome real/reactive powers exchange between bus AC and rectifier converter during fault on AC-side. Robust stability power in transmission using UPFC controlled by adaptive neural-network [6] and transient stability of AC-DC power systems is able to improve by HVDC controller based on neural network[7].

While, development of artificial intelligent control (ANC) is an active topic research and spread into power system and power electronics in recent years. Some the ANC schemes are applied into HVDC to suppress transient of direct current [8] [9], fuzzy type-2 control on PMSM drive combined by digital signal processing [10], grid-connected distributed generation controlled by fuzzy control [11], voltage source converter HVDC is regulated by ANFIS on space vector pulse width modulation[12] and distributed-statcom controlled by fuzzy to enhance the power quality in distribution system [13].

Rest of this paper is organized as follows: High voltage direct current transmission model is introduction in Section 2. Next, deign of additional ANFIS control is explored in Section 3. Result and analysis are explained in Section 4. And finally, conclusion is summarized in Section 5.

2 High voltage direct current transmission model

In order to simplify HVDC model, it can be developed by diagram blocks to represent the respective component such as: Sending-end, HVDC transmission, receiving-end and the HVDC transmission line. The sending-end (bus rectifier converter) is commonly built near power plant to supply the HVDC transmission system. Meanwhile, the receiving-end (bus inverter converter) is commonly developed near load center, and the power is distributed directly to consumer. The transmission HVDC is developed over long-distance area to connect the the sending-end and receiving-end. The HVDC system model in this research is provided by [14]. This model is shown in Fig. 1. The system is arranged By: An AC ideal source (Bus 1) 500 kV, 5000 MVA equivalent, freq. 60 Hz, angle 80 degrees. Converter bus (Bus 2) consist of device rectifier device, the function of this rectifier is to covert the AC voltage/current into DC voltage/current forms. And, the DC voltage/current are transmitted to Bus 3 through the HVDC transmission line. Bus 3, consist of inverter device, where the function of inverter is to convert the DC voltage/current into AC voltage/current forms again. The AC voltage/current are set to Bus 4. Bus 4 is modelled by 10000 MVA equivalent, voltage 345 kV, freq. 50 Hz and angle 80 degrees. Assumed, that the Bus 4 is functioned as a load bus. The power is delivered from Bus 1 to Bus 4 and transmitted via HVDC line in this scenario.

3 Design of additional ANFIS control

This section is conducted to design of additional ANFIS control. First stage is collect row-data-set from simulation of HVDC model [14] equipped by PI controller in various load. Next stage, is to develop an input-output matrix using [2 Inputs + 1 Output]$\times$ 5000 = 3$\times$ 5000 data-point. The input-output matrix is formed to train-data set and are used to train the additional ANFIS control. Program packet neuro-fuzzy designer (anfisedit tool) is used on learning

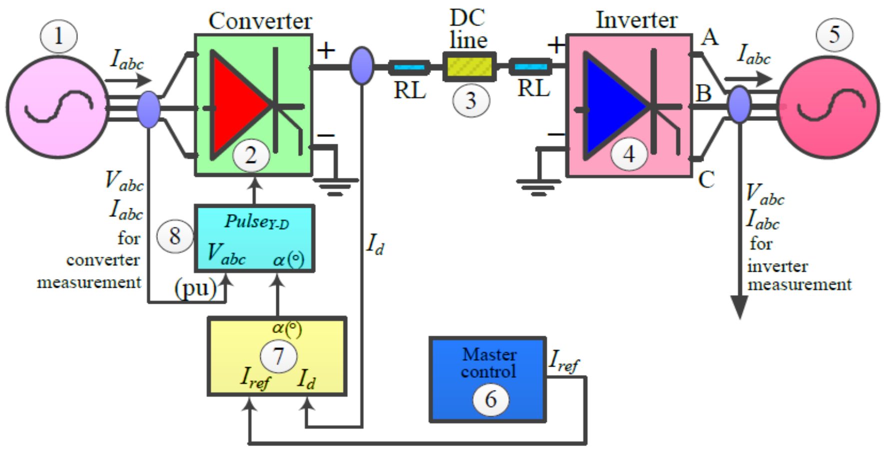

Fig. 1. Performance of proposed control

time in off-line mode. The train-data set are input into the anfisedit and some parameters are set as follows: Membership function (MF) type are Gaussian and linear MFs for the inputs and output MFs, respectively. Every training is taken on 20 epochs using back-propagation and least squares estimate methods. Fuzzy inference system (FIS) is built during the training processes and values of FIS parameter were generate and maintain automatically.

4 Result and analysis

Performance of additional ANFIS control is tested on an Intel core i5-7400 proc., 6.0 MB cache, 3.0 GHz and LGA 1151 personal computer. The Matlab/Simulink 7.0.9 (2013b) [15] packed program is used to simulate the HVDC model equipped by ANFIS control.

Fig. 3 shows simulation results of proposed control compared to convention (PI) control. In this scheme control, the PI parameters were set at the values 45, 4500 and 90 for the P, I and initial alpha degree, respectively, on current regulator of rectifier-side. The results are also listed in Table 1, for peak overshoot (M_p) and settling time (t_{st}) all control schemes.

It is shown that the peak overshoot was obtained at the values of 1.088 and 1.05 pu for PI and ANFIS controls, respectively, when the up-ramp rate at 21 pu/s. When the up-ramp rate was increased to 23 pu/s, the peak overshoot was

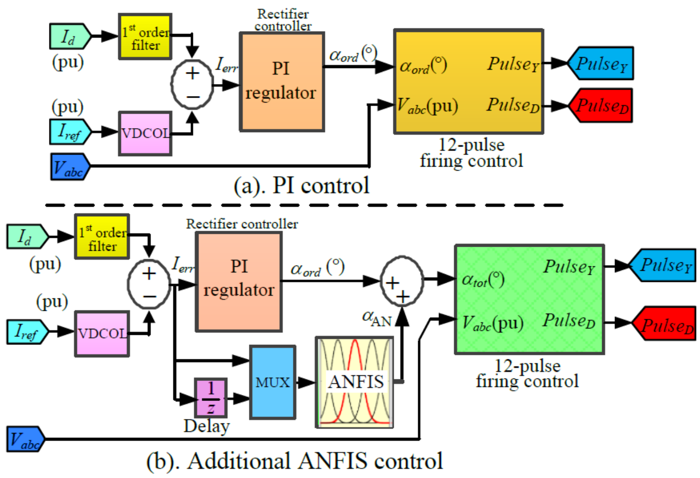

Fig. 2. Performance of proposed control

observed at the values of 1.106 and 1.068 pu for PI and ANFIS controls. Next, when the up-ramp rate was taken on 25 pu/s, the peak overshoot was achieved at the values of 1.118 and 1.077 pu for PI and ANFIS controls.

While, the settling time of PI and ANFIS controls was taken at times of 0.569 and 0.552 s, respectively. For the up-ramp rate was increased to 23 pu/s, the settling time of PI and ANFIS controls was achieved at the times of 0.572 and 0.556 s. And, the up-ramp rate was taken at 25 pu/s, the settling time of PI and ANFIS controls was observed at the times of 0.574 and 0.561 s, respectively.

Based on the simulation results, it is found that the proposed control is more effective to suppress the current transient on rectifier-side of HVDC than the conventional control. Also, the settling time of HVDC equipped by the proposed control is shorter than the settling time of HVDC equipped by the conventional control.

5 Conclusion

Additional control based on ANFIS is proposed in this Proposed control is able to maintain the current transient of converter-side in HVDC model. This result has been compared to the PI conventional control in order to validate the simulation result. The peak overshoot is achieved at the value of 1.077 pu for the proposed

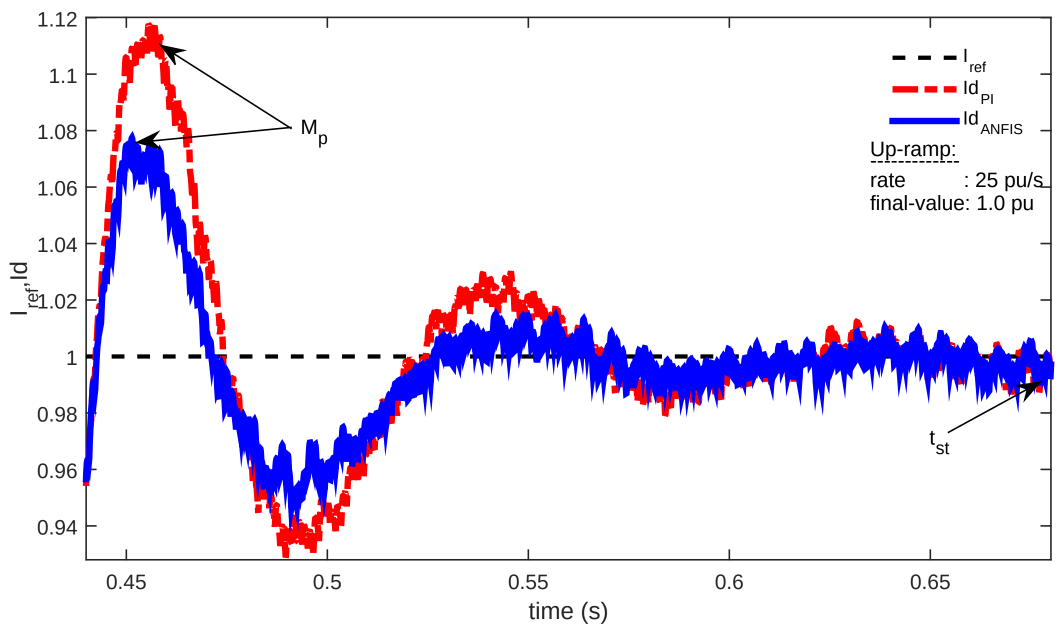

Fig. 3. Performance of proposed control

Table 1. Performance of proposed control

Up-ramp rate [pu/s]	M_p [pu]	t_{st} [s]	M_p [pu]	t_{st} [s]
	PI control		Additional ANFIS	
21	1.088	0.569	1.05	0.552
23	1.106	0.572	1.068	0.556
25	1.118	0.574	1.077	0.561

control. Meanwhile, the peak overshoot is achieved at the value of 1.118 pu for conventional control.

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